The Acute Effect of a Mandibular Repositioning Appliance on Force Production During an Isometric Clean Pull in Recreationally Trained Males

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THE ACUTE EFFECT OF A MANDIBULAR REPOSITIONING APPLIANCE ON FORCE PRODUCTION DURING AN ISOMETRIC CLEAN PULL IN RECREATIONALLY TRAINED MALES

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ABSTRACT

DANIEL HARTMAN: The Acute Effect of a Mandibular Repositioning Appliance on Force Production During an Isometric Clean Pull in Recreationally Trained Males (Under the direction of Dr. John Garner)

The use of a performance mouthpiece may cause notable performance changes in an isometric mid-thigh clean pull (iMTCP) due to altered muscular force production. The purpose of this study was to examine the effects of wearing various mouthpieces coupled with a clenching of the jaw on iMTCP force production. Three recreationally trained college-aged males (Age: 26.67 ± 2.89) volunteered to participate in three testing sessions separated by one week each. In the three sessions, the subject performed repetitions of an iMTCP under the following conditions: performance mouthpiece with jaw clenched (PMP-JC), performance mouthpiece with no clench (PMP-NC), traditional mouthpiece with jaw clenched (TMP-JC), traditional mouthpiece with no clench (TMP-NC), no mouthpiece with jaw clenched (NoMP-JC), and no mouthpiece with no clench (NoMP-NC). The iMTCP assessment was measured using a Jones Machine® with a modified fixed bar allowing the subject's strength to be transferred onto a force plate via ground reaction force. The force plate analyzed the subject's clean pull trials as the collected data was used to calculate the subject's peak force (Fz), normalized peak force (nFz), and rate of force development (RFD). There were no significant differences ($p > .05$) or interactions found in Fz between the test trials. Similarly, for nFz and RFD, no significant differences ($p > .05$) or interactions were found between conditions. Therefore, the subjects' iMTCP assessments showed no overall interactions or

improvements between conditions for this study. This goes to show that there is no overall benefit to wearing any sort of performance mouthpiece in hopes of generating a larger force production.

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Chapter I
INTRODUCTION

Many sports require the use of high amounts of muscular power output in shorter amounts of time. Those that are able to produce more amounts of power are generally better suited to succeed from an athletic standpoint. In the past few decades, an idea has been discussed linking the wearing of a mouthpiece to overall improvements in muscular power output. This idea has been received in different ways, as many researchers deemed it impossible that a mouthpiece could provide any benefits outside of oral protection, while others were interested in the idea and started to pursue it. Interestingly, some research showed mouthpiece related improvements ranging from improved muscular performance (Smith, 1978) to improved cortisol levels following exercise (Garner, 2011), which led to improved muscular recovery. Results such as these sparked interest in the idea as it spread into a more researched phenomenon. However, in order to understand how these improvements could be possible, it is first necessary to understand what power is and how it can relate to improved muscular strength and performance.

Power is defined as the rate of doing work, and is calculated by dividing work done by the time in which it is being done (Rodgers, 1984). Therefore, if a subject can increase the amount of work being done while simultaneously decreasing the time in which it is being done, the power output will be greater. From an athletic standpoint, an increase in power provides an advantage to the athlete and is manifested through an increase in strength. One of the main ways that this increase in power was expressed in relation to the mouthpiece research was through the term Rate of Force Development (RFD).

RFD is defined as the speed at which maximum muscular force is produced. In a sports scenario, if the RFD increases, the athlete is able to produce a greater amount of force in a shorter period of time. Ultimately, the desired outcome from an athletic standpoint is to increase the amount of force and the rate at which this force is developed in order to give the athlete an advantage. Under the idea of the mouthpiece, researchers were able to specify two different ideas that caused the improvements in strength and RFD.

The first idea suggested a realigning of the temporomandibular joint (TMJ) through the wearing of a mouthpiece. Improvements were caused as the mouthpiece placed the TMJ in its optimal position. This joint alignment is best explained through the ideas behind a Mandibular Orthopedic Repositioning Appliance (MORA). In 1977, Harold Gelb compiled a document describing what the MORA actually was and how it caused improvements in strength. He described the MORA as a mouthpiece with a splint used to keep the jaw in its physiological optimal position. Placing the jaw in its optimal position relieved stress from the TMJ and allowed for increases in strength. Studies involving the MORA actually showed increases in muscular strength and decreases in dental stress (Kaufman, 1980). In Kaufman's study, he was able to show improvements in vertical jump height, muscular strength, balance and agility in football players due to the application of the mouthpiece. Similarly, Kaufman found ways to relieve headaches and increase the pushoff strength of members of the US Olympic bobsled team by wearing the mouthpiece (Kaufman, 1980).

The second idea proposed that clenching down on the mouthpiece would activate larger amounts of muscle fibers through a phenomenon referred to as Concurrent Activation Potentiation (CAP). Under the idea of CAP, it was suggested that the clenching of the jaw could lead to an increased core muscle tension by activating the muscles remote from but concurrent with the prime mover (Ebben, 2006). CAP is best evidenced by the Jendrassik Maneuver, a situation where a person's fingers are harder to pull apart when the subject's teeth are clenched together. Essentially, the idea was that when one part of a motor cortex was activated by clenching the jaw, connections to other areas of the motor cortex (for example in the legs) were affected as well. This meant that by clenching the jaw and activating that area of the motor cortex, the subject's legs would experience an increase in strength via a concurrent activation of the muscle fibers of the lower extremities.

Interestingly, most studies involving the use of either a mouthpiece or CAP were examined separately, and those that examined them together studied instances of overall muscular strength and endurance, while few studies examined these phenomena during a specific type of muscular activity. Therefore, the purpose of this study was to look at these two ideas together, related to a specific muscular performance by examining the effects of wearing a mouthpiece and clenching the jaw on muscular performance evidenced during an isometric clean pull.

Hypotheses

Peak Vertical Force

H_{O1}: There will be no change in peak force due to wearing the mouthpiece or clenching the jaw.

H_{A1}: There will be an increase in peak force due to wearing the mouthpiece and clenching the jaw.

Literature involving vertical peak force shows an increase in this variable due to wearing the mouthpiece and clenching the jaw. An increase in vertical peak force would render the subject stronger by being able to produce larger amounts of power. Based on the literature, we expected to see the same results in the study.

Normalized Peak Force

H_{O2}: There will be no change in normalized peak force due to the mouthpiece or CAP.

H_{A2}: There will be an increase in normalized peak force due to the mouthpiece and CAP

Based on the literature involving mouthpieces and CAP, results show an increase in normalized peak force. Both of these variables are essentially the same in that they both measure peak force. However, normalized peak force gives a value relative to the subject's body weight. An increase in these variables corresponds to an increase in muscular strength and power output, which would cause more force to be produced by the subject during the iMTCP. From previous literature, peak vertical force and normalized peak force have shown increases due to wearing the mouthpiece and clenching the jaw, so therefore the same results are expected.

Rate of Force Development:

H_{O3}: There will be no change in rate of force development due to wearing the mouthpiece and clenching the jaw.

H_{A3}: There will be in increase in rate of force development due to wearing the mouthpiece and clenching the jaw.

From previous literature on wearing a mouthpiece and CAP, results have led to an increase in RFD. Essentially, the amount of force developed must increase, and the time in which this force is developed must decrease. An increase in RFD will shorten the time to maximal power output. From previous literature involving RFD, it is expected that the RFD will increase when wearing the mouthpiece and clenching the jaw.

Definitions

Ground Reaction Force: This term becomes very beneficial in determining power output. It is the force exerted by the ground on the subject's body during the isometric clean pull, specifying how much force the subject produced during the trial. It is equal in magnitude but opposite in direction to the force the force the foot exerts on the standing surface.

Peak Force: The maximum value of muscular force production recorded during the trial. This value is taken from the data recorded via the GRF. It is simply the highest recorded value and corresponds to the subject's maximum strength during the trial.

Time to Peak Force: The recorded time from the beginning of the trial to the time when the peak force was recorded. This value is important in determining how quickly the subject can generate force during a trial.

Rate of Force Development: The speed at which the subject produced the muscular force recorded during the trial. It is equal to the recorded force divided by the time taken to generate that force.

Isometric: An isometric muscle action is one in which the length of the muscle body does not change, but force is still generated by the muscle as the spindles fire.

Temporomandibular Joint: The hinge joint between the temporal bone and the lower jaw.

Potentiation: An increase in strength of nerve impulses along pathways, used to optimize power and force production.

Concurrent Activation Potentiation: An ergogenic advantage yielding an increase in muscular power output due to activation of additional muscles remote from the prime mover.

Mid Thigh Clean Pull: An Olympic weight lifting movement involving an extension of the legs with a flat back in order to pick up a barbell off the ground.

Jones Machine: A metal rack holding a fixed barbell at knee height over a force plate. The machine is modified so that the barbell cannot move, allowing all force generated to be measured by the force plate the subject stands on.

Force Plate: A part of the floor that is able to analyze the amount of force placed upon it. The subject stands on it so that the generated force during the clean pull is recorded.

CHAPTER II
REVIEW OF LITERATURE

The use of a mouthpiece for oral protection is very common in many contact sports. Initially, a mouth guard consisted of strips of a rubber-like material that were fitted to boxers' teeth before matches, an idea proposed by a London dentist named Woolf Krause (Reed, 1994). This idea was followed under the pretense that the mouthpiece was utilized solely for the athlete's oral protection. However, in 1977, an idea was presented examining the possibility that wearing a mouthpiece could lead to benefits outside of simply oral protection (Stenger, 1977). John Stenger examined the idea that wearing a mouthpiece could provide molar support and lead to a normalized posture of the head and neck. He examined this idea in Notre Dame football players suffering from malocclusion, which he defined as an imperfect positioning of the teeth when the jaw was closed (Stenger, 1977). The subjects he studied had all been benched due to some form of physical injury resulting in a decrease in performance. In each case he examined, wearing the mouthpiece led to an improvement in the alignment of the jaw, which further resulted in superior athletic performance. Whether the subject suffered from a brain injury or a back injury, the cases Stenger examined all showed an improvement in performance on the football field after wearing the mouthpiece. In this case, using a mouthpiece provided benefits outside of simple dental protection, which raised the question of not only what improvements could be produced, but why they occurred.

In 1978, researchers (Smith, 1978) started thoroughly examining whether wearing a mouthpiece while performing physical activity could produce any benefits outside of dental protection. Much of this initial research was conducted by Stephen Smith, who proposed that physical enhancements could potentially be caused by a realigning of the temporomandibular joint (TMJ) (Smith, 1978). In this study, Smith sought to obtain objective evidence indicating a correlation between muscular strength and the posture and condition of the jaw. This study was performed with subjects from the Philadelphia Eagles football team in correspondence with their coaching and athletic training staffs. A relationship between oral muscular strength and jaw posture to overall muscular strength and endurance of the body was measured by using wax bites for each subject that compared the natural jaw positions of the different players on the team.

The methods of the study were split into four parts. First, each subject went through an oral examination related to the subject's TMJ. Smith examined each subject's tooth clenching and grinding habits along with their history of concussions and usage of a mouthpiece. These were intended to give Smith any signs of a correlation between the subject's TMJ history and the results of the rest of the study.

The subjects also went through an oral orthopedic exam, in which the subject's TMJ was closely examined, along with their head and neck muscles. Smith was looking for any signs of muscular spasms or mandibular alignment shifts.

The last two parts of the study were divided into a subjective and objective measure of strength. In the subjective tests, the subject performed isometric deltoid press, in which the author pressed against the subject's arm, applying resistance as he sought to abduct his arm. This was performed both with the teeth held together and while wearing the wax bite. A decision was subjectively made between the subject and the author as to which scenario produced the greater amount of force (teeth together or with the wax bite). In the objective testing, the subject performed the same arm abduction, but with a Cybex II Dynamometer, which applied a specific amount of resistance to the subject's arm while he tried to resist both with his teeth together and while wearing the wax bite. In both cases, the dynamometer recorded the amount of force produced.

The results of the study showed that 32% of the subjects clenched and ground their teeth. 18 concussions were reported by 10 players, and only 24% of those that participated in the study actually wore a mouthpiece. In the subjective testing, 22 subjects produced higher amounts of strength while performing shoulder abduction, due to wearing the wax bite, while 3 showed no change in strength. In the objective testing, 4 were stronger, 2 showed no change, and 3 were weaker. Ultimately, these results led to several conclusions. Overall, there was a greater force production when the subjects wore the wax bite, supporting Smith's original hypothesis. However, due to the misalignment and jaw clicking (a failure of the jaw to slide in a fluid motion) in the TMJ of many of the subjects, the benefits of clenching on the wax bite and realigning the TMJ were nullified. Smith proposed a further aligning of the dental arches and preservation of the TMJ alignment in order to see the best results of aligning the TMJ with the wax bite. Ultimately, Smith's research did not support the correlation between the jaw posture and arm musculature to contract at a higher force with the wax bite. Four years later, Smith conducted another research project supporting the idea that specifically adjusting the mouthpiece for each subject would further increase its effects (Smith, 1982). In this research, the subject's arm muscle resistance was determined using an Isometric Deltoid

Press (IDP). Measurements were taken while the subject wore a non-adjusted mouthpiece and an adjusted mouthpiece. The data showed an increase in strength once the subject's mouthpiece had been adjusted, furthering the validity of some of the questions Smith had proposed about the effects of wearing a specific mouthpiece during exercise.

Additionally, in 1991, Kennon Francis performed his own research examining the physiological effects of wearing a mouthpiece, as he specifically measured the ventilatory and gas exchange effects of wearing a mouthpiece (Francis, 1991). His study included 10 males and 7 females ranging in age from 20-36 years. He measured Forced Expiratory Air Volume (FEV_1) and Peak Expiratory Flow Rates (PEF) in 4 different scenarios: no mouthpiece, maxillary mouthpiece (mouthpiece 1), and 2 different bimaxillary mouthpieces (mouthpiece 2, mouthpiece 3). During the study, the subject's VO_2 was measured while pedaling at light and heavy intensities on a cycle ergometer for 5 minutes.

The results of the study showed that wearing a mouthpiece significantly reduced FEV_1 by values of 8%, 12%, and 14% for mouthpieces 1, 2 and 3 respectively. PEF was also reduced by values of 7%, 15%, and 15.8% for mouthpieces 1, 2, and 3 respectively. There was no change in VO_2 while pedaling at a light load, although VO_2 did increase significantly while wearing the mouthpiece and pedaling at a heavy workload. Ultimately, wearing the bimaxillary mouthpiece produced the most significant improvements in FEV_1, PEF, and VO_2. Subjects of the study reported that wearing the bimaxillary mouthpiece did not further restrict airflow.

Following these studies, different researchers started diving further into this idea, examining other possible effects of wearing a mouthpiece during physical performance. One of the most important areas of research came from Harold Gelb, who produced a paper investigating the relationship between jaw posture and muscle strength in sports dentistry (Gelb, 1996). Much of what he discussed was centered around the usage of a mandibular orthopedic repositioning device (MORA) and the effects it could have on physical performance in an athletic setting. Gelb described the MORA as being similar to a regular mouthpiece, but also containing a splint used to keep the mandible in its physiological optimal position (Gelb, 1977). Gelb examines several studies in his article published in 1996 in order to better understand the range of benefits produced by wearing the MORA during exercise. He discusses cases of alleviated headaches and increases in pushoff strength in team members of the US Olympic bobsled and luge teams. These improvements in athletic performance were said to be due to wearing the MORA (Kaufman, 1980). The MORA was selected for four reasons: 1) to reduce headaches, 2) to increase to body's muscular strength, 3) to increase concentration, and 4) to relieve dental stress (Kaufman, 1980). The responses to wearing the MORA indicated that there were no negative effects, and sometimes even a decrease in headaches and an increase in pushoff strength.

Additionally, Gelb examines cases of improvement in muscular strength, vertical jump ability, and balance and agility in former football players (Kaufman, 1984). In this study, half of the football players wore the MORA, while half wore a conventional mouthpiece (CM). Kaufman analyzed 60 players' performance during practice and football games to examine the effects of the mouthpieces. The overall results favored the

MORA, showing a decrease in knee injuries and an increase in strength and player satisfaction. Also, the CM was not significantly favored (Kaufman, 1984). Overall, Gelb's research reinforced the idea that an optimal positioning of the mandible by wearing the MORA would lead to a wide variety of improvements in physical activity, which in turn sparked further interest in the possibilities of this field (Garner, 2009).

In this study, Garner and McDivvitt investigated the correlation between wearing a mouthpiece and producing improvements in airway openings and lactate levels (Garner, 2009). The study involved 10 college-aged males wearing mouthpieces while running for 30 minutes. Post exercise, the cross-sectional area of the oropharynx was measured. The results showed an increase in the diameter of the oropharynx while wearing the mouthpiece, which led to an improved breathing economy and increased muscular endurance. Overall, wearing the mouthpiece allowed the subjects to exercise at higher intensities for longer time periods due to an improved breathing economy, something entirely separate from increases in muscular performance, as was previously studied.

In the same study, Garner and McDivvitt also examined the change in lactate levels due to wearing the mouthpiece (Garner, 2009). The research suggested an improvement in endurance performance resulting from increased airway openings while wearing the mouthpiece. The improved lactate levels resulted from increased oxygen availability while running. Having improved lactate levels led to a smaller amount of lactic acid in the blood, which improved the subject's time to exhaustion. Having an improved time to exhaustion allowed the participants to run further before reaching exhaustion due to a buildup of too much lactic acid in the blood. Garner and McDivvitt postulated that this improved time to exhaustion (which ultimately resulted in improved overall physical performance) was due to the wearing of the mouthpiece, realigning the TMJ, and increasing the cross-sectional area of the oropharynx (Garner, 2009).

Additionally, research has been performed investigating improvements in visual and auditory reaction times due to the use of a mouthpiece (Garner, 2009). Garner and Miskimin performed a set of 30 trials investigating both visual and auditory performance, noting the time it took for a visual or auditory stimulus to be recognized. In both cases, subjects portrayed faster reaction times when wearing the mouthpiece. The results were significantly better for the auditory testing, while only slightly better when the visual stimuli were required. Researchers claim that the reason for the improvement in reaction times may be due to reduced stress in the TMJ when wearing the mouthpiece. Improved blood flow and neural transmission along the TMJ when wearing the mouthpiece could potentially increase oxygenated blood flow to other areas of the head and neck. Overall, this could lead to improvements in events such as reaction time, as auditory and visual reaction times may in some ways be modulated to improved blood flow. Ultimately, an improvement in visual and auditory reaction times assist in improving overall physical performance. Under this hypothesis, Garner and Miskimin were able to successfully uncover the idea of improved physical performance when wearing a mouthpiece.

Further research showed a change in chemical levels in the body while wearing the mouthpiece. Specifically, Dena Garner examined the effects of wearing a mouthpiece on cortisol levels in the body post exercise, hypothesizing that the levels would decrease (Garner, 2011). In this study, 28 Division I male football players performed 3 sets with 3 repetitions of hang cleans at various weights, with periods of 60-90 seconds of recovery. After each bout of exercise, a saliva sample was collected from the subject and analyzed for its levels of cortisol, along with a collected sample 10 minutes post exercise. Due to wearing the mouthpiece during these bouts of exercise, cortisol levels decreased significantly post exercise, while they increased post exercise in subjects who wore no mouthpiece. The idea behind this study was that biting down on the mouthpiece produced a reduction in masticatory stress due to the force plates over the molars in the mouth. This in turn led to a decreased stimulation of the motor area of the cerebrum, which followed into the hypothalamus, leading to a decreased release of cortisol from the hypothalamus. Ultimately, the benefit of decreased cortisol levels post exercise is that it has been linked to an increased ability to recover from exercise due to less skeletal muscle protein degradation. This could in turn produce more muscle recovery and lead to greater strength and physical performance.

Furthermore, research suggests an improvement in muscular endurance due to improved gas exchange levels caused by wearing the mouthpiece. Garner et al (Garner, 2011) conducted a study investigating the effects of mouthpieces on gas exchange parameters, including the volume of oxygen consumed (VO_2), the volume of oxygen consumed relative to body weight (VO_2/kg), and the volume of carbon dioxide produced (VCO_2). The study was performed with 16 physically fit college students ranging form 18 to 21 years of age. The study involved performing two 10-minute runs on a treadmill at 6.5 mph at 0% grade. The runs were performed at one of 3 conditions randomly assigned to the participants: with a mouthpiece, without a mouthpiece, or with nose breathing. The results of the study showed significant improvements in VO_2, VO_2/kg, and VCO_2 in the subjects who wore the mouthpiece. Ultimately, it was concluded that wearing the mouthpiece led to an improvement in gas exchange parameters, while further study is needed to explain the mechanisms involved. This improvement in gas exchange parameters leads to a higher muscular endurance and a longer amount of time before fatigue sets in.

One area more recently investigated is that of the effects of different varieties of mouthpieces on neuromuscular force and power production in men and women. Dunn-Lewis et al investigated the effects of customized Power Balance performance mouthguards (PB MG), over-the-counter boil and bite mouthguards (Reg MG), and no mouthguards (No MG) on aspects of vertical jump, 10-m sprint, bench throw, and plyo-press power quotient (3PQ) (Dunn-Lewis, 2012). The study involved 26 trained men and 24 trained women. Throughout the exercises, both heart rate (HR) and rate of perceived exertion (RPE) were measured. Expected differences for the data between males and females were also taken into account.

Initially, familiarization and baseline visits were performed to associate the subjects both with the mouthpieces and exercises being performed. The tests performed emphasized high-speed anaerobic power and force production (plyo press power quotient (3PQ), bench throw, and vertical jump). All subjects involved in the experiment were resistance trained and competed at various levels of different sports. The mouthpieces used were fitted with staff supervision.

For the bench throw test, the subject lay supine on a bench and performed 3 discontinuous throws of 30% body weight overhead. For the Counter Movement Vertical Jump (CMVJ), the subject performed 3 continuous, maximal effort jumps, with hands on hips to eliminate the addition of arm momentum to produce a higher jump. For the 3PQ measurement, the subject performed 30 seconds of continuous double leg presses on a plyo press machine at 125% body mass. The subject was to press as maximally as possible in a maximum power action. After this test, both HR and RPE were recorded.

The results of these studies showed a higher force output for bench throw when the customized mouthpiece was used. In men, the 3PQ power production was also higher with the customized mouthpiece. Lastly, an increase in rate of power production during the vertical jump was seen in men using the customized mouthpiece. It was ultimately speculated that the design of the mouth guards influenced and optimized the anatomical orientations of the jaw, producing an improvement in physical performance. All of these results show that under controlled laboratory conditions, a customized performance mouth guard positively impacted force and power production in power exercises (Dunn Lewis, 2012).

In one of the most recent studies, Allen (2014) investigated the effects of wearing a mouthpiece on various markers of physical performance, including functional balance, maximum muscle force production during a bench press exercise, and muscle power output during a countermovement vertical jump (CMVJ) (Allen, 2014). The study involved 20 recreationally active and exercise trained college males, ranging in age from 18-25 years. Each subject wore an Under Armour mouthpiece fitted by a local dentist while exercising under various conditions. For the functional balance assessment, an Equitest platform (NeuroCom, Inc.) was used to test the subject's balance. The system uses a force plate capable of shifting as the subject's balance is challenged. The balance conditions were changed to see if the subject's balance would change if eyes were opened, closed, or when the visual surroundings were fixed or not. For each trial, center of pressure was evaluated.

For the Max CMVJ Assessment, a vertical height-measuring device (Vertec) was used to measure the subject's vertical jump height, while a force platform measured the subject's ground reaction force (GRF). Rate of Force Development (RFD) was also calculated providing a correlation towards power output.

For the upper strength assessment, the subject's power output was analyzed via a one repetition maximum (1RM) for the bench press exercise. Subjects were required to make 3 visits, including 2 bouts of data collection. Under the three conditions, each subject's strength was analyzed to see which condition produced the greatest force development. Ultimately, Allen was able to uncover some of the ways wearing the mouthpiece could enhance performance, but suggested that further research be done to expand on some of these ideas.

Interestingly, as more and more research was conducted on this phenomenon of improved performance caused by wearing a mouthpiece, different ideas were proposed as to further changes produced by the mouthpiece outside of a realigninment of the TMJ. Some researchers even argued that the improvements caused by wearing the MORA are illegitimate, saying that the MORA does not have enough time to work, will only work on people with TMJ disorders, or due to the fact that it is not known whether the MORA actually places the mandible in the most optimal physiological position (Greenberg, 1981) (Burkett, 1982). Due to these arguments of controversial evidence, researchers branched out further into this field, examining other possibilities and effects of the mouthpiece. For example, recent studies have shown an increase in the musculature of the extremities, neck, and back best explained by a process called concurrent activation potentiation (CAP) (Ebben, 2006).

William Ebben recently produced an article explaining much of the phenomenon behind CAP (Ebben, 2006). He says that when exerting high amounts of muscular effort, it is common for people to clench their jaw or neck, oftentimes paired with a form of grunting known as the Valsalva maneuver. These practices often occur as an effort to increase core muscle tension and activate core muscles. Under these practices, it has been argued that activating muscles remote from, but concurrent with the prime mover may produce an ergogenic advantage (Ebben, 2006). This idea has been paired to the use of a mandibular orthopedic repositioning appliance (MORA), wondering if not only a repositioning of the TMJ, but also biting down (clenching) can affect the strength produced. This idea is best explained by the Jendrassik Maneuver (JM). Specifically, this technique involves patients clenching their teeth, hooking their flexed fingers together, and attempting to pull them apart. The JM ultimately increased the strength of the reflexes when the teeth were clenched. Theoretically, it was considered possible that JM like actions (contracting muscles not involved as the primary movers) could increase the acute strength expression of the primary movers. Under these ideas, Ebben sought to thoroughly explain the concept of Concurrent Activation Potentiation, to understand its mechanisms of action, and prescribe how it could be best applied to increase the quality of an acute training stimulus.

The Jendrassik Maneuver itself can be best explained by the H-reflex phenomenon. The H-reflex results as sensory fibers are stimulated, which produces an afferent discharge causing an excitatory potential in the motor neuron pool (Ebben, 2006). Thus, generating an action potential produces an efferent discharge causing the muscle fibers innervated by that neuron to activate. Ultimately, when one part of a motor cortex is activated [as seen in a Remote Voluntary Contraction (RVC)], connections to other areas of the motor cortex are affected as well.

However, the question still remains: how can activation of muscles in the jaw lead to a concurrent activation of alternative prime movers? The answer lies in the ideas behind the Cortical Connection Theory. Based on research performed on monkeys (Huffman, 2001), results showed interconnections between the cortical and somatosensory areas of different body parts. These results suggested the existence of cortical connections between forelimb and hindlimb for specific tasks seen in the monkeys. This resulted in the idea that the movement of one limb could be cortically connected to the movement of another. This same idea can be seen in humans, evidenced by Motor Overflow, where involuntary movements occur as a result of voluntary movements (Ebben, 2006). This phenomenon occurs generally in subjects with neurodegenerative diseases. Although these movements are generally unintentional and undesirable, studies have shown this idea of motor flow in some healthy individuals (Ebben, 2006). In a study done by Karistianis et al, movement of the ipsalateral hand resulted in the facilitation of the contralateral hand in both affected and normal subjects (Karistianis, 2004). Ultimately, Ebben was able to combine these researched ideas into a study involving CAP during the Countermovement Jump (CMVJ) to analyze its results (Ebben, 2006).

Ebben sought to evaluate the effect of CAP by evaluating jaw clenching and its effect on the Rate of Force Development (RFD), Time to Peak Force (TTPF), and Peak Force (PF). He performed the study with 14 male and female NCAA Division II athletes. They performed the task of jumping vertically off a force platform under 2 conditions:

maximally clenching on a dental vinyl mouthpiece (JAW) and no clenching while holding an open mouth (NON-JAW). The results showed a 19.5% increase in RFD under the JAW scenario, a 20.15 % decrease in TTPF under the jaw scenario, and no change in PF between the JAW and NON-JAW conditions. Ebben ultimately concluded that CAP was manifested through jaw clenching during the CMVJ, as evidenced by the enhanced RFD and TTPF. Ebben explained the results to be due to a combination of cortical influence as well as changes in postsynaptic membrane potential, manifested in the change in RFD without affecting PF.

Similarly, Ebben took many of the ideas attained in his first experiments and applied them to the realm of exercise involving closed kinetic chain, ground based exercises. The exercises were performed in two different environments. In the RVC condition, the subject performed the test exercises while clenching the jaw on a mouthpiece, gripping the barbell and pulling down into the trapezius, while simultaneously performing the Valsalva maneuver. In the non-RVC condition, the same exercises were performed, without RVC's. All exercises were assessed via a force platform. Results showed the RVC's producing an increase in the performance of the closed kinetic chain exercises by a value of 2.9-32.3%.

Ultimately, although vast amounts of research have shed much light on the relationships between intraoral devices, jaw clenching, TMJ alignment, and their effect on performance measures, much of this phenomenon remains a mystery. Therefore, further research is justified to increase the knowledge behind what makes this process work. It is of more importance than many realize as the implications of this research could lead to results bolstering the safety and competence of many areas of physical performance needed on a day to day basis.

CHAPTER III
METHODS

a) Participants:

Three currently physically active and recreationally trained males, ages 18-30, volunteered to participate in this study. Each subject was considered physically active if he participated in routine physical activity a minimum of three days per week for the previous month. Subjects were recruited via email and word of mouth throughout the Turner Center. Subjects had no reported history of temporomandibular disorder (TMD), no musculoskeletal, orthopedic, cardiovascular, vestibular, or neurological conditions, and also had previous experience with Olympic weight lifting, specifically the clean pull. All ACSM standards and requirements were met by the participants of this study (Pescatello, 2013).

Table 1: Anthropometric Measures

Participant Demographics:	Mean ± Standard Deviation:
Age (years)	26.67 ± 2.89
Mass (kg)	89.24 ± 10.81
Height (cm)	182.03 ± 2.93

b) Experimental Design and Methods:

Each subject required four laboratory visits. The first visit consisted of subject prescreening, obtaining informed consent, measurements such as height, mass, age, and test procedure familiarization. The remaining visits lasted approximately one hour and were scheduled exactly one week apart from the others, in order to account for diurnal variation. The following testing conditions for performing the procedures were randomized throughout the study: performance mouthpiece with jaw clenched (PMP-JC), performance mouthpiece with no clench (PMP-NC), traditional mouthpiece with jaw clenched (TMP-JC), traditional mouthpiece with no clench (TMP-NC), no mouthpiece with jaw clenched (NoMP-JC), and no mouthpiece with no clench (NoMP-NC).

Figure 1: Performance Mouthpiece

Subjects were instructed to maintain a consistent diet and hydration status, including a consumption of 32 oz water the night before the testing, and 12 oz one hour prior to the testing. Each subject provided a urine sample on testing days to be analyzed for specific gravity via dipstick (BTNX Inc; Markham, Ontario, Canada) to ensure proper hydration status). There was no necessary cutpoint, but the desired specific gravity reading was 1.000. A three-day dietary journal documenting all food and beverage intake was necessary to assess the subject's nutritional intake. Single day dietary recalls were also reported for each testing day. All dietary records were analyzed by a nutrient-analysis software, Nutrition Data Systems for Research (NDSR; Minneapolis, MN, version 2009). Subjects did not consume any non-prescription supplementations, with the exception of caffeine, if necessary. If the subject consumed caffeine, it was in normal amounts, consistent throughout the study. The subjects also maintained their normal sleeping patterns throughout the study. Lastly, all subject adherence to the requirements of the testing were assessed via oral questioning by the primary investigator.

c) Data Collection

There were two conditions of the jaw under which testing took place: jaw maximally clenched and jaw closed but not clenched. Under both of these conditions, the subject's maximal isometric strength was assessed via the isometric mid-thigh clean pull (iMTCP). Prior to testing, each subject performed 2 sets of 15 meters of jogging, walking lunges, high-knees, butt-kickers, and gait swings as a warm up protocol.

c) Equipment and Assessment Procedures-Isometric Clean Pull

Isometric clean pull assessment was measured using a Jones machine (BodyCraft, Inc., Sunbury, OH, USA), which was modified to fix the bar so that it could not move. The bar was fixed using Olympic lifting weights and adjustable straps, which were fixed to both ends of the bar so that it could not move. This allowed the subject's strength to be transferred onto the force plate (ground reaction force) on which he stood while performing the clean pull. A goniometer was used to standardize the subject's knee and hip angles at 140 and 125 degrees, respectively. The subject used nylon weightlifting straps to fix his hands to the bar, gripping the bar using a double overhand, closed grip, with the thumb wrapped around the bar. The nylon straps were used to negate potential advantages of subject's with larger hands and larger grip strength. When instructed, the subject performed the clean pull maximally for three seconds, with thirty seconds of rest between trials. The highest recorded ground reaction force (GRF) value was used for analysis. The GRF was the force applied by the subject's legs onto the force platform during the clean pull. The force platform analyzed the subject's clean pull trials and used the collected data to calculate variables such as peak force, rate of force development, and ground reaction force. Peak force was defined as the maximum muscular force production recorded during the trial by the force plate. Rate of force development was defined as how quickly the subject was able to produce the force analyzed during the individual trials and was used to correlate power output.

Figure 2: Isometric Mid-Thigh Clean Pull

d) Instrumentation and Data Processing

i) Force Platform

All clean pull trials were executed from a 600mm x 400mm force platform (Bertec Inc.,Columbus, OH, USA). The GRF data was used to identify the vertical peak force (Fz) value, normalized peak force (nFz), and rate of force development (RFD). The RFD described how quickly the subject was able to produce the force necessary to perform the clean-pull. This was calculated as a slope of the GRF curve over time intervals of 0-120, 0-200, and 0-250 msec. Normalized peak force was determined by dividing the peak force by the subject's body weight, expressed as a function of body weight (nFz).

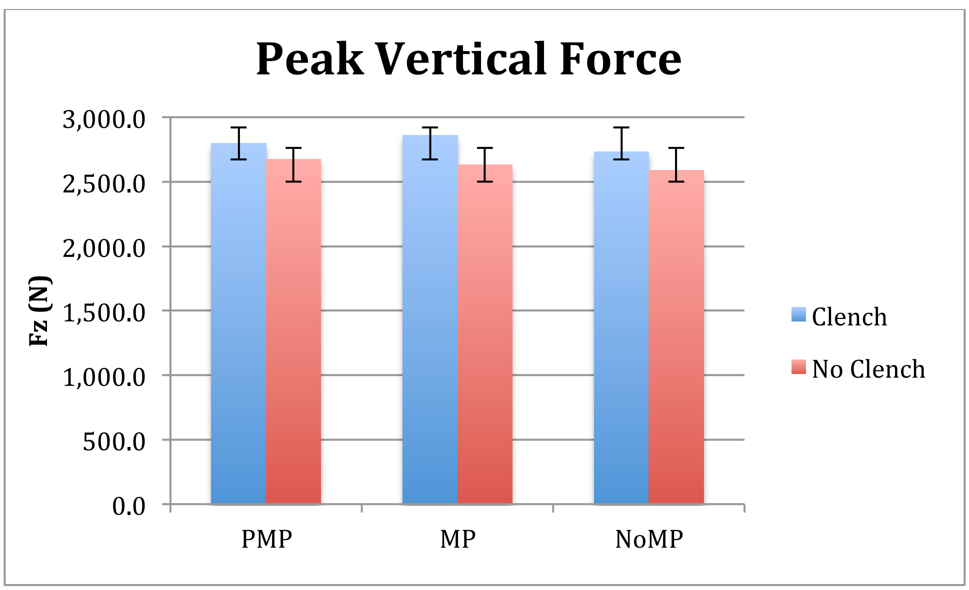
e) Statistical Analysis

The study followed a repeated measures design where each subject was his own control due to the fact that he performed the entire study under each of the different conditions. A sampling rate of 1,000 Hz was used for the study, along with Interaction and main significance was analyzed by conducting a 3 x 2 (mouthpiece x clench condition) ANOVA for repeated measures. Bonferroni correction was used to detect condition difference if main effect significance was present. A p value of $\leq .05$ was used for the study.

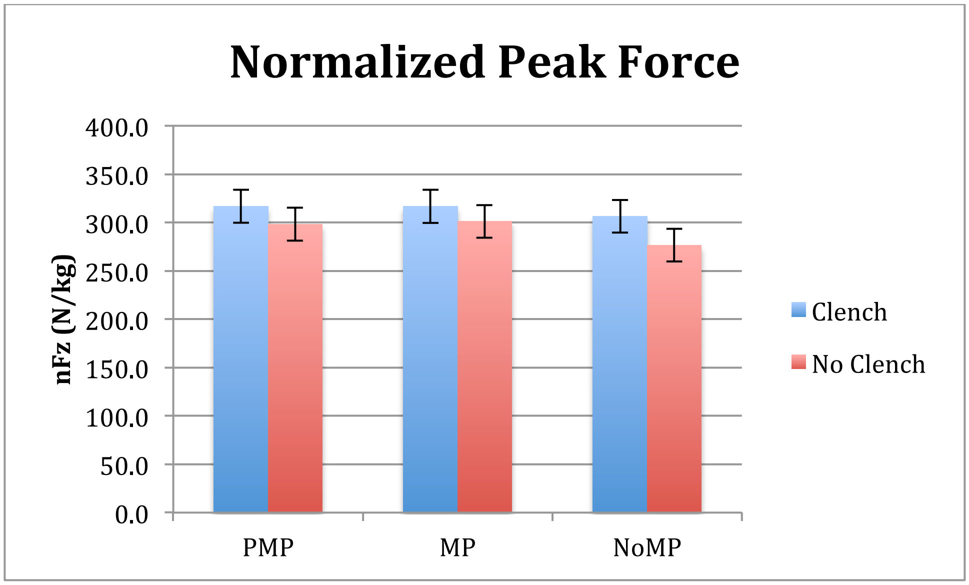
CHAPTER IV
RESULTS

For vertical peak force (Fz), a 3 x 2 Repeated Measures Anova revealed no main effect for the MP condition (p= .194) or the clench condition (p= .379). Furthermore, no interaction was found between conditions (p= .865). For normalized peak force (nFz), data revealed no main effect for the MP condition (p= .465) or the clench condition (p= .219). Also, no interactions were found between conditions (p= .817). Lastly, for RFD, there was no main effect for the MP condition (p= .397) or the clench condition (p= .066). Additionally, no interaction was found between conditions (p= .617).

Peak Vertical Force Graph:



Normalized Peak Force Graph:



Rate of Force Development Graph:

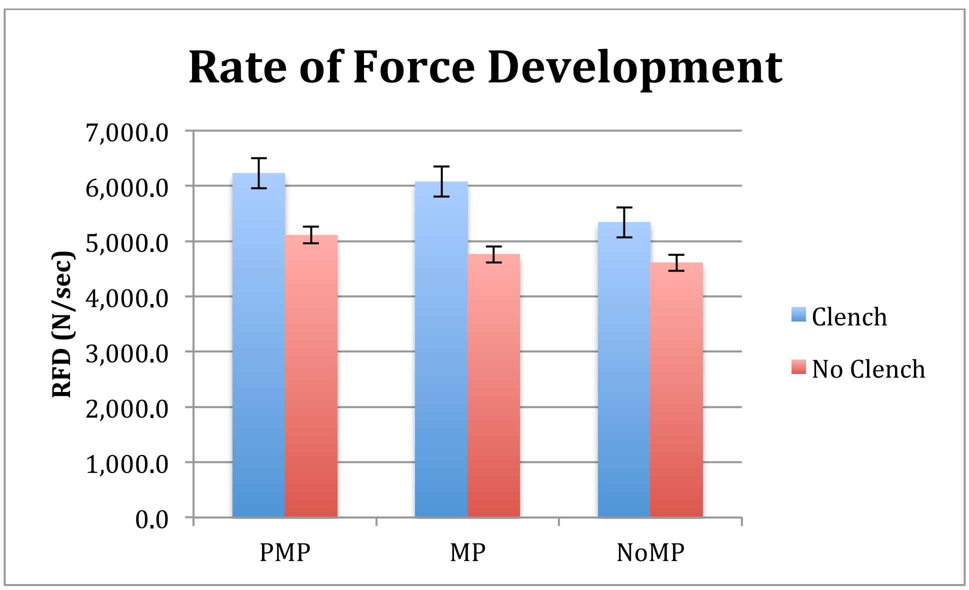


Table 2: Mean Data and Standard Deviation

	PMP		MP		NoMP	
	Clench	No Clench	Clench	No Clench	Clench	No Clench
Fz (N)	2797.3 ±249.7	2676.5 ±246.5	2858.9 ±419.8	2633.0 ±195.6	2734.0 ±287.9	2588.6 ±204.4
nFz (N/kg)	316.7 ±40.5	298.2 ±11.8	316.6 ±9.3	301.2 ±40.0	306.5 ±20.5	276.4 ±28.7
RFD (N/s)	6227.0 ±748.5	5110.2 ±970.7	6076.8 ±1051.2	4760.5 ±1459.4	5342.6 ±1769.5	4609.8 ±1817.0

CHAPTER V
DISCUSSION

The purpose of this study was to investigate the effects of wearing a mouthpiece and clenching the jaw on force and RFD during an iMTCP. The study also examined the interactions between these conditions to examine if any combination of conditions was optimal. The results showed that wearing the mouthpiece, clenching the jaw, or doing both simultaneously did not have any effect on force produced or RFD during the clean pull.

Ultimately, this does not fit with most of the current literature available on this topic. According to the ideas behind the MORA, wearing the mouthpiece would not only relieve stress placed on the TMJ but would also reduce athletic stress, yielding higher amounts of strength. This is due to the claims that the MORA placed the TMJ in its optimal position. Similarly, according to Kaufman (1980), the MORA had the ability to increase the pushoff strength of the US Olympic bobsledders. Other studies showed that wearing the mouthpiece could improve other areas of exercise such as cortisol levels after exercise and improved muscular endurance (Garner, 2011).

Additionally, based on the ideas behind CAP, clenching the jaw during exercise should lead to improved muscular strength due to the recruitment of extra muscle fibers not associated with the prime movers. These ideas were transferred into studies involving vertical jump (Ebben, 2006) and showed improvements in vertical jump height as a result of clenching the jaw. He also showed increases in the magnitude of remote voluntary contraction trials while clenching the jaw whose values increased by sometimes up to 32% (Ebben, 2006). However, this was not the case when performing the repetitions of the iMTCP, as the data results showed no significant changes or improvements between conditions. After evaluating the data, several conclusions can be drawn as to why wearing the mouthpiece and clenching the jaw did not lead to improved muscular strength.

First of all, the study only involved three participants. Based on the time allowed to complete the study, there was not enough time to add any more participants and collect their data since collection time takes three weeks. Therefore, it is possible that the effects of the mouthpiece and clenching the jaw simply were not prevalent in these three subjects but are prevalent in others. Almost all of the literature evaluated in this study involved at least 30 participants in order collect data that was reliable. Therefore, the improvements in muscular strength shown in those studies could be due to the fact that a sufficient number of participants were involved in the study. In order to get more reliable data, it would be necessary to use more participants in the study in order to have a larger pool of data to evaluate.

Additionally, it is possible that the mouthpieces used did not in fact place the subject's jaw in its optimal position. The idea behind the MORA is that it reduces stress by realigning the jaw, but in the cases of these three subjects, it is possible that the mouthpieces used did not realign the jaw as would be necessary to improve strength production. Based on the literature, researchers would bring in a professional dentist to properly fit the mouthpiece for each participant. This made sure that the mouthpiece was working properly and the TMJ was properly aligned.

Moreover, it is possible that since the iMTCP only lasted around three seconds on average per repetition, there was simply not enough time for the TMJ alignment or jaw clenching to have any effect on the subjects. In Kaufman's study (1980) the mouthpieces were worn the entire time the bobsledders were performing a run. Similarly, Garner (2011) had the subjects wear the mouthpiece the entire time they exercised. When the mouthpiece was used in sporting events, there was ample time for the TMJ to be aligned and CAP to have its effect, but in the case of a single IMTCP, it is possible that there was not enough time for the subject to receive any benefits for the clean pull.

The applications of these conclusions apply for two different scenarios. First, in order for the mouthpiece to have its effect, it is necessary that the subject have a professional dentist align his mouthpiece. That way, the dentist can make sure that the TMJ is in fact placed in its optimal position. Also, it is necessary that the subject uses the mouthpiece and can clench the jaw in a situation where there is enough time for CAP to have its proper effect on the subject. The subject must also be consciously aware to clench the jaw when performing physical activity in order to see improvements.

Further direction and research in this field is ultimately necessary in order to better understand the effects of TMJ realignment and CAP in cases of force production. In the future, it would be necessary to add more subjects to the study in order to have larger amounts of data from which to analyze. Additionally, it would be beneficial to have a professional dentist on hand to personally fit each subject with his mouthpiece. Lastly, it would be beneficial to organize the study in such a way that the subject would have time for the effects of CAP to be seen.

CONCLUSION

In conclusion, the results of this study have shown that the acute effects of TMJ alignment and CAP while wearing a mouthpiece and clenching the jaw do not lead to improvements in force production during an iMTCP. Although the literature states that such an improvement should be observed, results showed otherwise in this study. This could be due to the fact that there were only three participants in the study, or that there was not enough time for the TMJ alignment and CAP to have their effects on the participant during the clean pull. Ultimately, further study is required to more sufficiently understand this phenomenon, with more emphasis placed on the number of participants involved in the study, the way the mouthpiece is aligned in each individual participant, and under what muscle activity condition the mouthpiece is being used.

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